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Polar Cap Patch Dynamics

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14. ABSTRACT

Under this grant University of Oslo (UiO) has covered the annual fee for AFRL's all-sky imager at the Kjell Henriksen Observatory in Longyearbyen. On request UiO we have provided AFRL optical data from our instrumentation at Ny-Ålesund, Longyearbyen and Andenes, North-Norway, and TEC and scintillation data from our NovAtel GSV 404B GPS receivers located at Oslo and Ny-Ålesund.
The primary objective has been to obtain a better understanding solar wind impacts on the polar ionosphere which are of central importance to current space research and of relevance for space weather applications. The science problem complex is related to the formation of polar cap patches, transport of patches across the polar cap, and plasma instability mechanisms associated with polar cap patches. This project has contributed to 13 peer review publications with UiO co-authorship.
The report is organized as follows. Section 2 provides key information about the UiO optical instrumentation. Sections 3, 4 and 5 specifies the time intervals our instrumentation was operated the winters of 2010/2011, 2011/2012 and 2012/2013, respectively. Section 6 summarizes the science production (titles and abstracts for the 13 papers). Section 7 states that we have made no inventions, and Section 8 lists the core UiO personnel during this project.

15. SUBJECT TERMS

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FINAL TECHNICAL REPORT

on

POLAR CAP PATCH DYNAMICS

by

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25 April, 2013

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Content

1. Introduction

Under this grant University of Oslo (UiO) has covered the annual fee for AFRL's all-sky imager at the Kjell Henriksen Observatory in Longyearbyen. On request UiO we have provided AFRL optical data from our instrumentation at Ny-Ålesund, Longyearbyen and Andenes, North-Norway, and TEC and scintillation data from our NovAtel GSV 404B GPS receivers located at Oslo and Ny-Ålesund.

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2. UIO's OPTICAL INSTRUMENTATION

Station	***Abbrev.***	***Geogr.lat***	***Geogr. lon***	***CGM Lat***	***CGM long***
Ny-Ålesund	NYA	78.92	11.95	75.25	112.08
Longyearbyen	LYR	78.20	15.82	75.12	113.00
Andenes	AND	69.30	16.03	66.45	100.37

All-Sky Cameras :

2011/2012 season

LYR 3" system (UiO_ASI-1) : 630.0, 557.7, 427.8 nm + NIR

NYA 3" system (UiO-ASI-2): 630.0, 557.7 nm
NYA 4" system (UiO_ASI-4): 630.0, 557.7, 427.8, 777.4 nm

AND 3" system (UiO_ASI-3) : 630.0, 557.7 nm

2011/2012 season:

LYR 3" system (UiO_ASI-1) : 630.0, 557.7, 427.8 nm + NIR
LYR 4" system (UiO_ASI-5) : 630.0, 557.7, 427.8, 777.4 nm

NYA 3" system (UiO-ASI-2): 630.0, 557.7 nm
NYA 4" system (UiO_ASI-4): 630.0, 557.7, 427.8, 777.4 nm

AND 3" system (UiO_ASI-3) : 630.0, 557.7 nm

One minute filter cycle for all systems 2011/2012 and 2012/2013:

00	6300
08	5577
23	5577
30	6300
38	5577
53	5577

The UiO_ASI-5 and UiO_ASI-6 are the new Keo Sentry 4" Scientific Imagers from 2012. They have a filter wheel with 6 thermally stabilized filters. The camera is a Pixis 2048B_eXcelon CCD camera from Princeton Instruments. The UiO_ASI-6 will be in operation in Ny-Ålesund next winter.

3. Campaign periods for the 2010/2011 winter

3.1 Operation periods Ny-Ålesund

29 Nov - 13 Dec 2010
28 Dec - 10 Jan 2011
25 Jan - 8 Feb 2011

3.2 Operation periods Longyearbyen

8 Nov - 18 Nov 2010
24 Nov - 16 Dec 2010
28 Dec - 29 Dec 2010
02 Jan - 03 Jan 2011
08 Jan - 11 Jan 2011
24 Jan - 8 Feb 2011

3.3 Operation periods Andøya

18 Nov - 19 Nov 2010
26 Nov - 15 Dec 2010
28 Dec - 7 Jan 2011
24 Jan - 10 Feb 2011

4. Campaign periods for the 2011/2012 winter

4.1 Operation periods Ny-Ålesund

28 Oct - 4 Nov 2011
19 Nov - 5 Dec 2011
16 Dec – 1 Jan 2012
12 Jan – 26 Jan 2012
13 Feb – 24 Feb 2012

4.2 Operation periods Longyearbyen

25 Oct - 4 Nov 2011
19 Nov - 5 Dec 2011
16 Dec - 1 Jan 2012
12 Jan - 26 Jan 2012
13 Feb - 24 Feb 2012

4.3 Operation periods Andøya

25 Oct - 4 Nov 2011
23 Nov - 5 Dec 2011

16 Dec - 1 Jan 2012
13 Jan - 27 Jan 2012
13 Feb - 24 Feb 2012

4.4 Operation of EISCAT Svalbard Radar during the January 2012 campaign
The science objective was to determine the evolution of large-scale plasma structure and irregularity regions in polar cap patches as they convect along a chain of heavily instrumented ground stations across the polar cap. Ground stations include Resolute Bay, Qaanaaq, Station Nord, and Svalbard. Radars at Sondrestrom and Resolute Bay were also operated. The EISCAT Svalbard radar provided F-region plasma density and line-of-sight ion velocities along the Scandinavian end of the chain, coordinating with ground measurements in Svalbard and Station Nord, Greenland, especially to provide horizontal coverage over Station Nord and altitude coverage along the chain between Nord and Svalbard.

15Jan2012	07:00	12:00	RUN PatchTrack 5h
15Jan2012	18:00	24:00	RUN PatchTrack 6h
17Jan2012	18:00	24:00	RUN PatchTrack 6h
19Jan2012	18:00	22:00	RUN PatchTrack 4h

5. Campaign periods for the 2012/2013 winter

5.1 Operation periods Ny-Ålesund

20 Oct - 23 Oct 2012
8 Nov - 22 Nov 2012
4 Dec - 19 Dec 2012
1 Jan - 15 Jan 2013
1 Feb - 12 Feb 2013

5.2 Operation periods Longyearbyen

12 Nov - 21 Nov 2012
4 Dec – 20 Dec 2012
1 Jan - 16 Jan 2013
1 Feb - 12 Feb 2013

5.3 Operation periods Andøya

9 Nov - 17 Nov 2012
2 Dec - 13 Dec 2012
1 Jan - 17 Jan 2013
1 Feb - 15 Feb 2013

6. Summary of Science Production

The project grant has supported operation of instruments for scientific measures of space weather phenomena, and the results achieved have been published in peer reviewed journals. An overview of the science progress is provided in the form of Title, Citation details and Abstract for each of the published articles.

Title 1: Stratification of east-west plasma flow channels observed in the ionospheric cusp in response to IMF B_Y polarity changes.

Citation: Rinne, Y., J. Moen, H. C. Carlson, and M. R. Hairston (2010), Stratification of east-west plasma flow channels observed in the ionospheric cusp in response to IMF B_Y polarity changes, *Geophys. Res. Lett.* , 37 , L13102, doi:10.1029/2010GL043307.

Abstract: During a period of predominantly north-westward flow for IMF B_Z negative and IMF B_Y positive, a sequence of three distinct negative excursions of IMF B_Y resulted in a train of three eastward directed flow channels, interleaved by westward flow enhancements propagating into the polar cap. The high resolution of the EISCAT Svalbard radar data enables us to track formation and movement of the flow channels, which are interpreted as a sequence of intermittent reconnection alternating between different reconnection sites. Our observations are consistent with the view that a new region of reconnected flux manifests as development of a distinct flow channel near the polar cap boundary, and that successive events stay separated while pushing each other into the polar cap. Each flow channel will remain separated from neighboring channels mapping to different reconnection sites as long as the magnetic tension force with its associated field aligned current systems is maintained.

Title 2: In situ measurement of a newly created polar cap patch

Citation: Lorentzen, D. A., J. Moen, K. Oksavik, F. Sigernes, Y. Saito, and M. G. Johnsen (2010), In situ measurement of a newly created polar cap patch , *J. Geophys. Res.*, 115 , A12323, doi:10.1029/2010JA015710.

Abstract: The Investigation of Cusp Irregularities 2 sounding rocket was launched 5 December 2008 at 1035 UT. We present an overview of the associated solar wind and auroral conditions, and we look in detail at the relationship between poleward moving auroral forms (PMAFs) and the creation of polar cap patches using ground-based optical and radar data as well as in situ data from the rocket payload. The solar wind was found to be dominated by a stable interplanetary magnetic field (IMF) $B_z < 0$ and by an IMF $B_y > 0$ situation. The aurora was characterized by a series of PMAFs throughout the period

of interest. Associated with each PMAF were polar cap patches seen to emerge from the most poleward location of the PMAFs. On the basis of the available data, we present a conceptual model explaining the creation of the polar cap patches under the given solar wind and ionospheric conditions.

Title 3: On the entry and transit of high-density plasma across the polar cap

Citation: Oksavik, K., V. L. Barth, J. Moen, and M. Lester (2010), On the entry and transit of high-density plasma across the polar cap , *J. Geophys. Res.* , 115 , A12308, doi:10.1029/2010JA015817.

Abstract: Observations are presented from SuperDARN and the EISCAT Svalbard Radar of two intense polar cap patch events on 6 February 2001. The interplanetary magnetic field (IMF) was dominated by a large positive By component, and for both events the electron density exceeded 10^{12} m^{-3} in the *F* region. With SuperDARN we tracked the events all the way across the polar cap, from the dayside Svalbard sector to the nightside Alaska sector. The flow speed was highly dynamic and pulsed, and both patches underwent substantial rotation in the polar cap. On the nightside the leading edge had become the trailing edge. It suggests that the first patch to enter the polar cap on the dayside may not always be the first patch to reach the nightside; plasma might be stagnant in the polar cap or even overtaken. The study also provides evidence that momentum transfer in the dayside polar cap can last significantly longer than 10 min after reconnection, especially for extremely long field lines where IMF By is dominating, i.e., on "old open field lines." Knowledge of the solar wind driver and the coupling processes is therefore extremely important for predicting the motion of a polar cap patch event across the polar cap. Gradients in the plasma flow associated with the rotation of the extreme density may in itself lead to a stronger growth of ionospheric irregularities. These irregularities may continue to grow all the way across the polar cap. The result is more efficient creation of ionospheric irregularities.

Title 4: Motion of polar cap arcs

Citation: Hosokawa, K., J. I. Moen, K. Shiokawa, and Y. Otsuka (2011), Motion of polar cap arcs , *J. Geophys. Res.* , 116 , A01305, doi:10.1029/2010JA015906.

Abstract: A statistics of motion of polar cap arcs is conducted by using 5 years of optical data from an all-sky imager at Resolute Bay, Canada (74.73°N, 265.07°E). We identified 743 arcs by using an automated arc detection algorithm and statistically examined their moving velocities as estimated by the method of Hosokawa et al. (2006). The number of the arcs studied is about 5 times larger than that in the previous statistics of polar cap arcs by Valladares et al. (1994); thus, we could expect to obtain more statistically significant results. Polar cap arcs are found to fall into two distinct categories: the B_y-dependent and B_y-independent arcs. The motion of the former arcs follows the rule reported by

Valladares et al. (1994), who showed that stable polar cap arcs move in the direction of the interplanetary magnetic field (IMF) B_y. About two thirds of the arcs during northward IMF conditions belong to this category. The latter arcs always move poleward irrespective of the sign of the IMF B_y, which possibly correspond to the poleward moving arcs in the morning side reported by Shiokawa et al. (1997). At least one third of the arcs belong to this category. The B_y -dependent arcs tend to move faster when the magnitude of the IMF B_y is larger, suggesting that the transport of open flux by lobe reconnection from one polar cap compartment to the other controls their motion. In contrast, the speed of the B_y -independent arcs does not correlate with the magnitude of the B_y. The motions of both the B_y -dependent and B_y -independent arcs are most probably caused by the magnetospheric convection. Convection in the region of B_y -dependent arcs is affected by the IMF B_y, which indicates that their sources may be on open field lines or in the closed magnetosphere adjacent to the open-closed boundary, whereas B_y -independent arcs seem to be well on closed field lines. Hence, the magnetospheric source of the two types of arc may be different. This implies that the mechanisms causing the motion and generation of arcs could be different between the two types of polar cap arc.

Title 5: Convection surrounding meso-scale ionospheric flow channels

Citation: Rinne, Y., J. Moen, J. B. H. Baker, H. C. Carlson, (2011), Convection surrounding meso-scale ionospheric flow channels, J. Geophys. Res., 116, A05213, doi:10.1029/2010JA015997.

Abstract: We have included data from the EISCAT Svalbard radar and DMSP spacecraft into the SuperDARN polar cap convection patterns in order to study how the ionospheric convection evolves around a sequence of transient, meso-scale flow channel events in the dusk side of the cusp inflow region. On a northwestward convection background for IMF B_Y positive and B_Z negative, a sequence of three eastward flow channels formed over the course of one hour in response to three sharp IMF rotations to IMF B_Y negative and IMF B_Z positive.

The first and third channels, due to IMF B_Y negative periods of ~13 and more than 30 minutes respectively, develop in a similar manner: they span the entire ESR field-of-view and widen polewards with elapsing time since their first appearance until the IMF rotates back. The convection patterns are consistent with the line-of-sight data from the ESR and DMSP within a 10 minute adaption time. The flow lines form twin vortex flow with the observed channel being the twin vortices centre flow. The fitting algorithm was pushed to its limit in terms of spatial resolution in this study. During parts of the channel events the suggested twin cell flow is not in agreement with our physical interpretation of the flow channels as reconnection events since cell closure is suggested across an anticipated non-reconnecting open closed boundary. For these times we present simulated patterns which have been arrived at by a combination of looking at the raw data and examining the fitted convection patterns.

Title 6: Decay of polar cap patch

Citation: Hosokawa, K., J. I. Moen, K. Shiokawa, and Y. Otsuka, (2011), Decay of polar cap patch, J. Geophys. Res., 116, A05308, doi:10.1029/2010JA016287,

Abstract. We report an event in which a polar cap patch was detected with an all-sky imager (ASI) at Resolute Bay, Canada (74.73^{0}N, 265.07^{0}E; AACGM latitude 82.9^0) on the nightside. The patch stopped its anti-sunward motion associated with a northward turning of IMF and stayed within the field-of-view (FOV) of the ASI for more than 1 h. When the patch stagnated, its luminosity decreased gradually, which allows us to investigate how the patch plasma decayed in a quantitative manner. The decay of the patch can be quantitatively explained by the loss through recombinations of O^+ with ambient N_2 and O_2 molecules, if we assume the altitude of the optical patch to be around 295 km. The derived altitude of the patch around 295 km is much higher than the nominal value at 235 km obtained from the MSIS-E90/IRI2007 models, indicating that climatological models such as IRI are not suitable for describing actual density profile of patches. This is probably because the loss process was much faster in the lower-altitude part of the patch; thus, the peak altitude of the patch increased as it traveled across the polar cap due to rapid recombination at the bottomside of the F region. This suggests that we should employ higher emission altitude when we investigate optical patches transported deep into the nightside polar cap. Such an information is important when we compare the optical data with other instruments such as coherent radars and GPS scintillation measurements by mapping the all-sky image on the geographic coordinate system with an assumption of the patch emission altitude.

Title 7: On the relationship between flux transfer events, temperature enhancements and ion upflow events in the cusp ionosphere

Citation: Skjæveland, Å., J. Moen and H. C. Carlson, (2011), On the relationship between flux transfer events, temperature enhancements and ion upflow events in the cusp ionosphere, J. Geophys. Res., 116, A10305, doi:10.1029/2011JA016480.

Abstract: A transit of the dayside aurora across the field-of-view of the EISCAT Svalbard Radar occurred on 20 December 1998. This offered an excellent opportunity to study the spatial structure of the cusp/cleft aurora using meridian scanning photometer and incoherent scatter radar. We were able to identify distinct regions of upflow driven by ion heating (type 1) and upflow driven by electron heating (type 2) around poleward moving auroral forms, a transient auroral feature tied to flux transfer events. A quiet period before the auroral transit allowed us to estimate a neutral temperature profile,

which enabled calculation of the ion-neutral relative wind. We found evidence for purely ion heating-driven upflow equatorward of the cusp auroral boundary, and for electron heating-driven upflow near the equatorward auroral boundary. The greatest upflow occurred near the center of the cusp aurora when both ion and electron temperatures were enhanced. The observed upflows were greater than expected from ambipolar diffusion alone, suggesting that ion-neutral frictional heating did contribute to upflow events in most cases. The great variability observed in ion temperature indicates that the ion flow was greatly structured within the aurora. Type 1–2 upflows may be considered as spatial structures of active cusp. Upflows are observed at various times in their evolution, and one upflow event, estimated to be 5–10 minutes old, showed a lifting of the F region of some 100 km, indicating a hybrid of type 1 and type 2.

Title 7 : Reversed flow events in the cusp ionosphere detected by SuperDARN HF radars

Citation: Oksavik, K., J. Moen, E. H. Rekaa, H. C. Carlson, and M. Lester, (2011) Reversed flow events in the cusp ionosphere detected by SuperDARN HF radars, J. Geophys. Res., 116, A12, doi:10.1029/2011JA016788.

Abstract: We present several examples of reversed flow events (RFEs) from the cusp ionosphere. RFEs are 100–200 km wide flow channels opposing the background plasma convection. RFEs were discovered a few years ago by the incoherent scatter European Incoherent Scatter Svalbard Radar. In this paper we show that coherent scatter Super Dual Auroral Radar Network (SuperDARN) HF radars can also see RFEs. We report a close relationship between RFEs and the development of HF backscatter power and spectral width. Wide spectra were seen near the edges of the RFEs (i.e., associated with the flow shear), and there was a significant increase in SuperDARN HF backscatter power when the RFE expanded. This increase in power is much faster than anticipated from the gradient drift instability alone, supporting the hypothesis that RFE flow shears foster rapid growth of Kelvin-Helmholtz instabilities. That decameter-scale irregularities form so rapidly should be an important guide to the development of instability theory for cascade of plasma irregularities from larger to smaller scale sizes.

Title 8: First in-situ measurements of HF radar echoing targets

Citation: Moen, J. I., K. Oksavik, T. Abe, M. Lester, Y. Saito, T. A. Bekkeng, and K. S. Jacobsen, (2012), First in-situ measurements of HF radar echoing targets, Geophys. Res. Lett., doi:10.1029/2012GL051407.

Abstract: The sounding rocket Investigation of Cusp Irregularities 2 (ICI-2) was launched into the cusp ionosphere over Svalbard to investigate the production of decameter scale irregularities in the electron plasma associated with HF radar backscatter. The main mission objective was to obtain high-resolution measurements of decameter scale electron plasma irregularities and to quantify the growth rate for the gradient drift instability (GDI). At the 5.7 kHz sampling rate of the absolute density

measurements, ICI-2 has provided the first documentation in terms of absolute electron density measurements of how 10-m structures are located on km scale electron density gradients. ICI-2 traversed a cusp electron density structure created by ongoing soft precipitation. 10-m scale irregularities were generated at km scale density gradients. The estimated growth time for the GDI process was 10–50 seconds.

Title 9: Multi-scale features of solar terrestrial coupling in the cusp ionosphere

Citation: Moen, J., H. C. Carlson, Y. Rinne, Å. Skjæveland, Multi-scale features of solar terrestrial coupling in the cusp ionosphere, J. Atmos.Terr. Phys. (2012), 87-88, p11-19, , doi:10.1016/j.jastp.2011.07.002.

Abstract : The large scale dynamics of the cusp ionosphere is directly controlled by the solar wind and the orientation of the interplanetary magnetic field. The IMF B_Y controlled east-west movement of the of the poleward moving forms (PMAFs), separating from the cusp, is consistent with the magnetic tension pull of newly opened flux, which is a key feature tying the auroral phenomenon of PMAFs to flux transfer events (FTEs) at the magnetopause. The central region of an FTE is a mesoscale flow channel, bounded by a pair of Birkeland current sheets on each flank. Systematic observations by EISCAT Svalbard Radar, meridian scanning photometers and all-sky imagers have provided us further insight into key processes of the cusp ionosphere such as how FTEs/PMAFs control ion upflow events, and how transient magnetopause reconnection processes segment a stream of high density solar EUV plasma into polar cap patches at the polar cap boundary. We have found a close causal relationship between formation of plasma patches and onset of scintillation by a previously unrecognized process. We have discovered a new category of flow-channels, Reversed Flow Events that may (RFEs) that appear related to a signature of Birkeland currents arcs, and may be signature of the MI-coupling/inverted V rather than mapping directly to the magnetopause. This review paper concentrates on a niche of cusp studies made by high-resolution radar and optical measurements.

Title 10: In-situ measurements of plasma irregularity growth in the cusp ionosphere.

Citation: Oksavik, K., J. Moen, M. Lester, T. A. Bekkeng, and J. K. Bekkeng, (2012), In-situ measurements of plasma irregularity growth in the cusp ionosphere. J. Geophys. Res., 117, A11301, doi:10.1029/2012JA017835.

Abstract: The Investigation of Cusp Irregularities (ICI-2) sounding rocket was launched on 5 December 2008 from Ny-Ålesund, Svalbard. The high-resolution rocket data are combined with data from an all-sky camera, the EISCAT Svalbard Radar, and the SuperDARN Hankasalmi radar. These data sets are used to characterize the spatial structure of *F* region irregularities in the dayside cusp region. We use the data set to test

two key mechanisms for irregularity growth; the Kelvin-Helmholtz (KH) and gradient drift (GD) instabilities. Except for a promising interval of 4–6 km irregularities, the KH growth rate was found to be too slow to explain the observed plasma irregularities. The time history of the plasma gives further support that structured particle precipitation could be an important source of kilometer- to hectometer-scale "seed" irregularities, which are then efficiently broken down into decameter-scale irregularities by the GD mechanism.

Title 11 : First-principles physics of cusp/polar cap thermospheric disturbances

Citation : Carlson, H. C., T. Spain, A. Aruliah, A.Skjaeveland, and J. Moen (2012),, First-principles physics of cusp/polar cap thermospheric disturbances, Geophys. Res. Lett., 39, L19103, doi:10.1029/2012GL053034.

This first-principles examination of physics driving the cusp/polar upper thermosphere response to significant input energy impulses discloses previously unappreciated factors essential to thermospheric input-response relationships. The physics essential to coupling of cusp input-response processes is detailed, to make previously unexplained up-to-doubling of air density and drag near 400 km not only understandable but expected, if not inevitable. Presented as a common natural consequence of magnetic reconnection near the magnetopause, this energy-coupling from sun to upper atmosphere is through familiar processes, but by inadequately appreciated linkages. The underlying physics applies more broadly than this. We trace a logic path that should clarify the input-response, and lay out a path which if followed should enable most existing time-dependent 3-D global thermospheric models to significantly improve the realism of their representation and prediction of cusp/polar thermosphere disturbances to transient energy sources. We illustrate the concept with a sample model-run incorporating representative data.

Title 12: Space weather challenges of the polar cap ionosphere

Citation: Moen, J., K. Oksavik, L. Alfonsi, Y. Daabakk, V. Romano, and L. Spogli, (2013), Space weather challenges of the polar cap ionosphere, J. Space Weather Space Clim. 3 (2013) A02, DOI: 10.1051/swsc/2013025.

Abstract: This paper is reviewing research on polar cap ionosphere space weather phenomena conducted during the COST action ES0803. The main part of the work has been directed towards the study of plasma instabilities and scintillations in association with cusp flow channels and polar cap electron density structures/patches, which is considered as critical knowledge in order to develop forecast models for scintillations in the polar cap. We have approached this problem by multi-instrument techniques that comprise the EISCAT Svalbard Radar, SuperDARN radars, in-situ rocket, and GPS scintillation measurements. The discussion section aims to unify the bits and pieces of

highly specialized information from several papers into a generalized picture. The cusp ionosphere appears as a hot region in GPS scintillation climatology maps. Our results are consistent with the existing view that scintillations in the cusp and the polar cap ionosphere are mainly due to multi-scale structures generated by instability processes associated with the cross-polar transport of polar cap patches. We have demonstrated that the SuperDARN convection model can be used to track these patches backwards and forward in time. Hence, once a patch has been detected in the cusp inflow region, SuperDARN can be used to forecast its destination in the future. However, the high-density gradient of polar cap patches is not the only prerequisite for high latitude scintillations. Unprecedented high resolution rocket measurements reveal that the cusp ionosphere is associated with filamentary precipitation giving rise to km scale gradients onto which the gradient drift instability can operate very efficiently. Cusp ionosphere scintillations also occur during IMF B_Z north conditions, which further substantiates that particle precipitation can play a key role to initialize plasma structuring. Furthermore, the cusp is associated with flow channels and strong flow shears, and we have demonstrated that the Kelvin-Helmholtz instability process may be efficiently driven by reversed flow events.

Title 13: Multi-instrument Observations from Svalbard of a Traveling Convection Vortex, Electromagnetic Ion Cyclotron Wave Burst, and Proton Precipitation Associated with a Bow Shock Instability

Citation: M. J. Engebretson, T. K. Yeoman, K. Oksavik, F. Søraas, F. Sigernes, J. I. Moen, M. G. Johnsen, V. A. Pilipenko, J. L. Posch, M. R. Lessard, B. Lavraud, M. D. Hartinger, L. B. N. Clausen, T. Raita and C. Stolle, Multi-instrument Observations from Svalbard of a Traveling Convection Vortex, Electromagnetic Ion Cyclotron Wave Burst, and Proton Precipitation Associated with a Bow Shock Instability, J. of Geophys. Res., Published Online : 18 MAR 2013, doi: 10.1002/jgra.50291

Abstract: An isolated burst of 0.35 Hz electromagnetic ion cyclotron (EMIC) waves was observed at four sites on Svalbard from 0947 to 0954 UT January 2, 2011, roughly one hour after local noon. This burst was associated with one of a series of ~50 nT magnetic impulses observed at the northernmost stations of the IMAGE magnetometer array. Hankasalmi SuperDARN radar data showed a west-to-east (antisunward) propagating vortical ionospheric flow in a region of high spectral width ~ 1-2° north of Svalbard, confirming that this magnetic impulse was the signature of a traveling convection vortex (TCV). Ground-based observations of the H_α line at Longyearbyen indicated proton precipitation at the same time as the EMIC wave burst, and NOAA-19, which passed over the west coast of Svalbard between 0951 and 0952, observed a clear enhancement of ring current protons at the same latitude. Electron precipitation from this same satellite indicated that the EMIC burst was located on closed field lines, but near to the polar cap boundary. We believe these are the first simultaneous observations of EMIC waves and precipitating energetic protons so near to the boundary of the dayside magnetosphere. Although several spacecraft upstream of Earth observed a steady solar wind and

predominantly radial IMF orientation before and during this event, data from Geotail (near the morning bow shock) showed large reorientations of the IMF and substantial decreases in ion density several minutes before it, and data from Cluster (near the afternoon bow shock) showed an outward excursion of the bow shock simultaneous with it. These upstream perturbations suggest that a spontaneous hot flow anomaly (SHFA), a bow-shock-related instability, may have been responsible for triggering this event, but do not provide enough information to fully characterize that instability.

7. Disclosure of inventions

I certify that there are no subject inventions to declare during the performance of this grant.

8. Key Personnel at UiO

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